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EDITORIALS

The 35,000 h. p. reversing engine described by Mr. Nibecker in his article in the Proceedings of the Engineers' Society of Western Pennsylvania is one of the most impressive sights in a steel mill which is itself a house of wonders. When one stops to realize that the low pressure cylinders of this engine are considerably over six feet long and five feet high he begins to appreciate its tremendous size. The smoothness with which it runs, however, and with which it reverses, is still more impressive. The engine runs practically without load until the ingot reaches the blooming mill, when the full load is applied immediately, and the engine takes this load almost without a quiver. As soon as the ingot passes through the mill the load is removed and the engine again runs free until after it reverses and the ingot reaches the mill on its return passage. The ease with which Texaco oils lubricate this unit is, to the lubricating engineer, the most impressive sight of all. It would be hard to imagine steam cylinder conditions more difficult to handle than those presented by this engine, but the lubrication is just as efficient as in the case of an ordinary 100 h. p. engine. This is but another of the many instances where Texaco products have proved their great efficiency.

The field of animal and vegetable oils has been gradually invaded by the various mineral oils until the amount of these fixed oils now used for lubricating purposes is almost negligible. The latest invasion has occurred in marine engine lubrication and, as Lieut. Kauffman has shown in his article, reprinted in this issue, Texaco Altair Oil, which is the oil on the Navy contract for this purpose, has proven in practically every way equal if not superior to compounded oil.

LUBRICATION OF ONE OF THE LARGEST REVERSING ENGINES IN THE WORLD

AN interesting article on one of the largest Twin Tandem Compound Reversing Engines in the world was published some time ago in the *Proceedings of the Engineers' Society of Western Pennsylvania*.* The high pressure cylinders of this engine are 46″ x 60″ and the low pressure cylinders 76″ x 60″, and it is rated at 35,000 h. p. This engine drives a 44″ reversing blooming mill which rolls 20″ x 22″ ingots. The engine is described in the article as follows:

The engine is operated condensing using steam at 140 lb. gauge pressure at the throttle valve and exhausting into a 28 in. vacuum. The condenser used is a 120 in. steam pipe supported barometric condenser, the air pump being 14 in. and 36 in. by 24 in. reciprocating type, with automatic inlet and outlet valves.

In Figure 1 is shown the engine and air pump, the condenser being located directly outside of the building. The steam separator is shown directly back of the engine. The low pressure cylinders are placed adjacent to the beds on either side. The engine is direct connected to the mill but separated from it by means of a brick wall. The mill pinions and couplings being shown in the figure.

Figure 2 represents a diagrammatic arrangement of one side of the engine and valve gear, showing the method of control. This control is rather novel, and we believe quite new in this country, although it has been used in Europe with varying details of arrangement. It will be noticed that the mechanism is operated by a single lever, as shown at *A*, Figure 2. This lever, which is located in the pulpit, operates the relay valve which controls the steam to the reversing cylinder, operating both the reversing links and the throttle. The reversing piston is cushioned by means of a suitable oil cylinder connected to the reversing gear cross head.

The three positions of the main reversing lever and cross head are shown by points *1*, *2*, and *3*. The pressure of the steam through the throttle valve and the point of

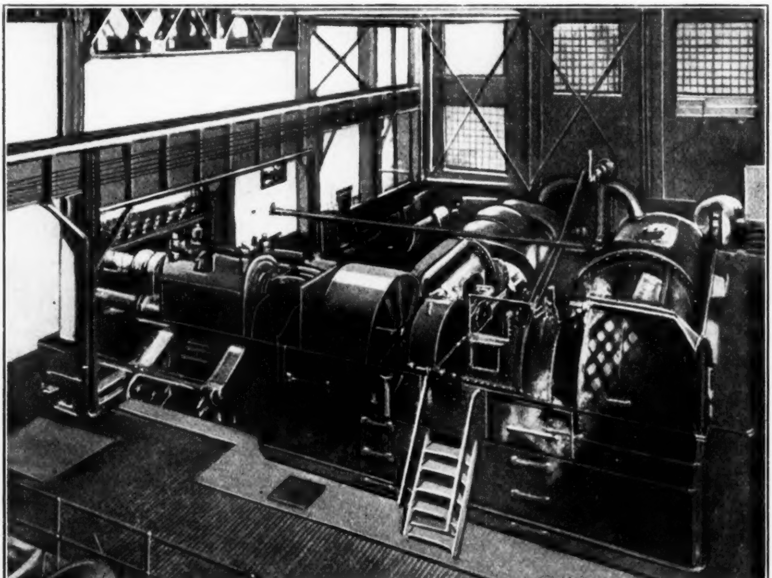

Figure 1—General Arrangement of Mill Drive.

* Karl Nibecker, "Test of Large Reversing Engine and Rolling Mill," in *Proceedings of the Engineers' Society of Western Pennsylvania*, July, 1914, p. 533.

cut-off with which the engine works are thus both determined by the motion of this cross head. It is therefore essential that the engine when operating under light loads must work with a combination of throttle and cut-off control.

The throttle valve is arranged so that its opening does nòt occur with the beginning of the movement of the reversing lever from its center position. A certain amount of lap is provided so that the valve gear is moved an appreciable amount from its neutral position before the steam valve is opened. When the throttle valve opens, steam is admitted through auxiliary ports in the main piston valves. By this combination of lap on the throttle valve and auxiliary ports in the main valves of the engine, it is possible to start the engine at any position of the cranks. The auxiliary ports are in operation during the regular running of the engine, but are too small to affect the economy of the engine or the shape of the indicator cards.

The high pressure and low pressure steam valves of the engine, which are of the piston type, are arranged in a straight line, so that both can be driven from one rocker, this construction greatly simplifying the valve gear.

With the arrangement of reversing cylinder, control of the throttle valve, and links as above described, it will be seen that the ordinary "plugging" effect is greatly reduced and also it is impossible for the operator to run the engine with full cut-off and control the speed by means of simply throttling the steam. The saving due to the large amount of steam which is consumed in plugging the engine and also the losses which occur due to running with throttled steam and late cut off are greatly reduced by this system.

Figure 3 illustrates the engine looking from the cylinders towards the cranks. The steam throttle valve is shown in the foreground and is controlled by means of rod shown, which is operated by reversing piston. The control shaft to the pulpit is indicated passing across the left hand engine and through the building. This shaft is seen in Figure 4, driving the smaller of the two rods leading to the reversing mechanism. The larger rod in Figure 4 running from the reversing mechanism is the throttle valve control. The links are operated by means of reversing cylinder through suitable connections under the floor plates. The auxiliary steam valve is shown at the distant end of the reversing cylinder in the center of this figure, the oil cushioning cylinder being in the foreground.

Figure 5 illustrates the pulpit and back end of the mill. The size of the ingots delivered to the mill were measured at this point as the ingots were delivered by ingot buggy.

Figure 6 is a general view of the mill at the front, showing the shears at which the final length of the bloom was measured. . . .

It will be seen that 34.5 per cent. of the total available work is consumed in accelerating and retarding the rotating and reciprocating parts, 9.8 per cent. is used in

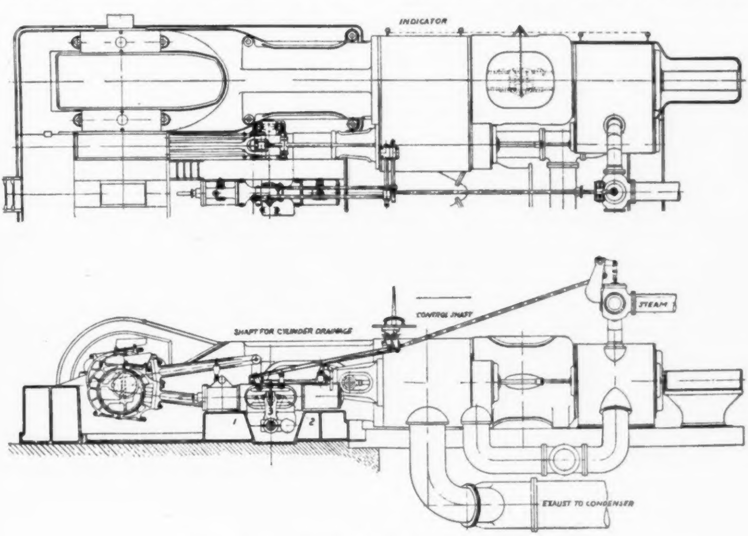

Figure 2—Diagram of Control Mechanism.

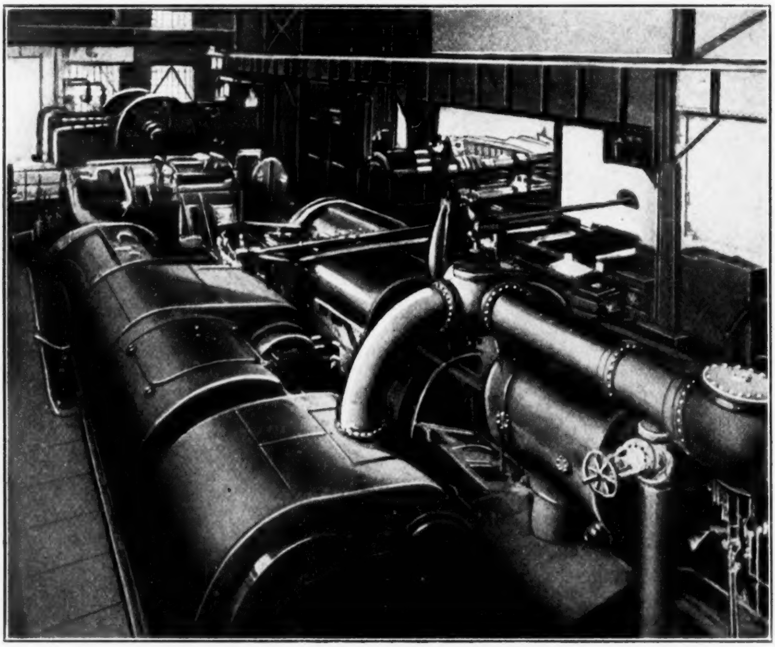

Figure 3—Steam End of Engine.

friction and only 55.7 per cent. is actually consumed in deforming the steel. It thus appears that an inordinate amount of work is consumed by the engine in accelerating and retarding the moving parts. This amount is due to the weight of moving parts used and the excessive amount of counterbalancing done, this being 60 per cent. of the reciprocating parts.

Tests which have been made on other engines, would indicate that this amount of power may be larger than necessary. There should be little or no trouble in bringing this value down to not more than 15 per cent. Engines have been tested where this quantity was even lower.

It might be possible to build an engine with much lighter moving parts and providing suitable means for increasing and decreasing the counterbalance weights, so as to produce the required smooth running without consuming such a large amount of power.

It must be borne in mind however that the engine in question runs without the slightest vibration, and has shown no wear on boxes, pins, or bearings. This of course, is a desirable feature, but we must not be led astray by these conditions of running to a point where we constantly spend too much in steam consumption in order to obtain an absolutely smooth running engine.

The amount of power consumed in friction, 9.8 per cent., is exceptionally low, the values of other engines running from 14 to 25 per cent. This low value is obtained by large short bearings properly lubricated and perfect alignment. The pinions and bearings are also of the highest type of construction being carefully machined and aligned. The couplings used are of special design and machined to eliminate all lost motion and reduce the friction and wear to a minimum. The cut pinions, special couplings and bearings, we believe reduces the friction very materially.

The steam consumed per I. H. P. hour was found to have a maximum value of 23.6 per cent. after adding the 30 per cent. for condensation, leakage, etc. In spite of this large addition, the average value of steam consumed per I. H. P. hour exhibits a value of about 21 lb. per I. H. P. hour. This value compares very favorably and in fact, is almost identical with the steam per I. H. P. hour determined for high class three high mills, while the best steam consumption yet obtained in this country for reversing condensing engines was in the neighborhood of 35 lb. With this exceptionally good steam consumption, if the power required to accelerate the moving parts were reduced to a reasonable amount, say 15 per cent., the steam consumption per unit of elongation

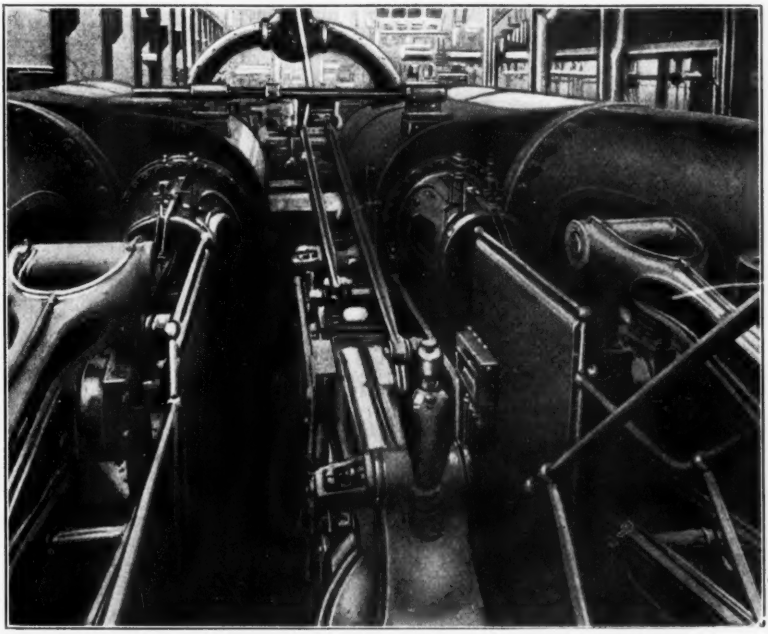

Figure 4—Valve Gear of Engine.

per ton of metal would be reduced nearly 30 per cent., thus giving a steam consumption which would be absolutely phenomenal for this country. The steam consumption as obtained per unit of elongation compares very favorably with tests of other engines which are operating in this country and also with engines abroad. In fact, the reduction of the amount of power consumed in acceleration would produce a steam consumption per unit of elongation which would be better than the value as given by Puppe, as the best practice for condensing engines in Europe. The correct value of steam consumption per I. H. P. hour as shown by steam meter is 18 lb. This is indeed, we believe, better than any other yet obtained.

The addition of 30 per cent. to the dry steam as figured from the cards may seem excessive for an engine of this class, but in the absence of definite knowledge at the time this engine was run, this value was used. We have since learned that this value is approximately correct.

The saving due to the steam held in the cylinder during compression was found to be about 10 per cent. With the ordinary type of gear there is practically no steam saved in compression and this feature is usually dropped.

The engine has been run non-condensing and the steam consumption determined with the result that the steam used is approximately 25 per cent. higher than when running condensing, thus by condensing a reversing engine, it is possible to obtain a saving of 25 per cent. With a simple engine exhausting into a low pressure turbine, even when equipped with a regenerator, it is very doubtful if it is possible to effect an equal saving. Where it is possible to use the exhaust from a reversing engine for heating the boiler feed water, it is of course, the most efficient way to use the heat in the exhaust steam.

It has been stated that it is impossible to produce a high vacuum in the cylinders of the reversing engine, but this fact has been clearly disproved by this engine. A vacuum of 25 inches in the low pressure cylinder is obtained with 28 inches in the body of the condenser. . . . .

The engine has been found to reverse quickly, despite the prediction that this would not be the case with a single lever control.

After repeated observations, it has been found that the engine will change from a speed of 60 r. p. m. in one direction to 30 r. p. m. in the opposite direction in less than $2\frac{1}{2}$ seconds. The engine has rolled 500 ingots in 12 hours with an average elongation of 8, proving that it is possible to manipulate the engine and mill very quickly. The

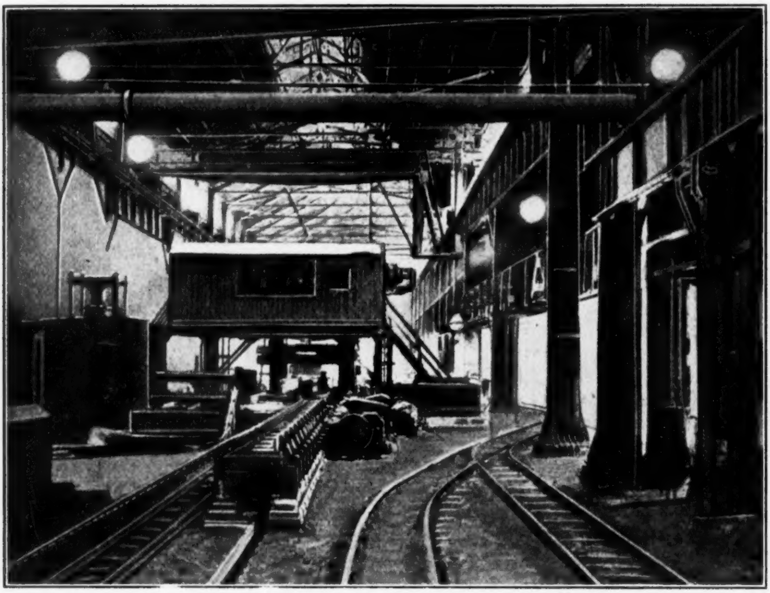

Figure 5—View of Pulpit and Rear End of Mill.

weight of these 500 ingots was 1298 tons and no ingots were rolled in less than 15 passes. The average time of rolling a 2½ ton ingot as described in this test was 85 seconds from the time it reached the rolls until it left the rolls. The time of manipulation and of actual rolling is found to be about equal, i.e., approximately 42½ seconds in actually deforming the steel and an equal amount in manipulating the piece.

From observations taken on the control lever of the engine, it was found that it requires approximately ⅜ of a second to move the lever through its entire travel, and 1½ seconds are required from the beginning of the movement of the reversing lever until the links are fully reversed. From ½ to 1 second is the time required for the links to reach their new extreme position after the lever has reached its new extreme position.

Texaco cylinder oil is used for the lubrication of this unit. The steam cylinders are equipped with two 7-feed Richardson-Phenix mechanical lubricators, the introductory points of which are as follows: one line from each lubricator runs into the steam line adjacent to the separator, which is about twelve feet behind the throttle valve; one line into branches from the throttle valve; one line enters at the top of each high pressure cylinder at a point near the center of each cylinder; one line at the top of low pressure piston valves at each end, and one line runs into the middle of the low pressure cylinders. Two lines are used for the lubrication of the reversing gear cylinder and valve. The piston rods are lubricated by hand-feed cups.

On account of the intermittent operation of this gigantic engine, and because of condensation, the steam cylinder and valve lubrication constitutes one of the most difficult lubricating conditions to be met in modern practice. However, due to the quality of the oil used as well as to the modern appliances for introducing it, no difficulty has ever been experienced in showing the same degree of efficiency as has been brought about in engines of much lesser size and operating under conditions much easier to cope with.

A Texaco engine oil of pale color

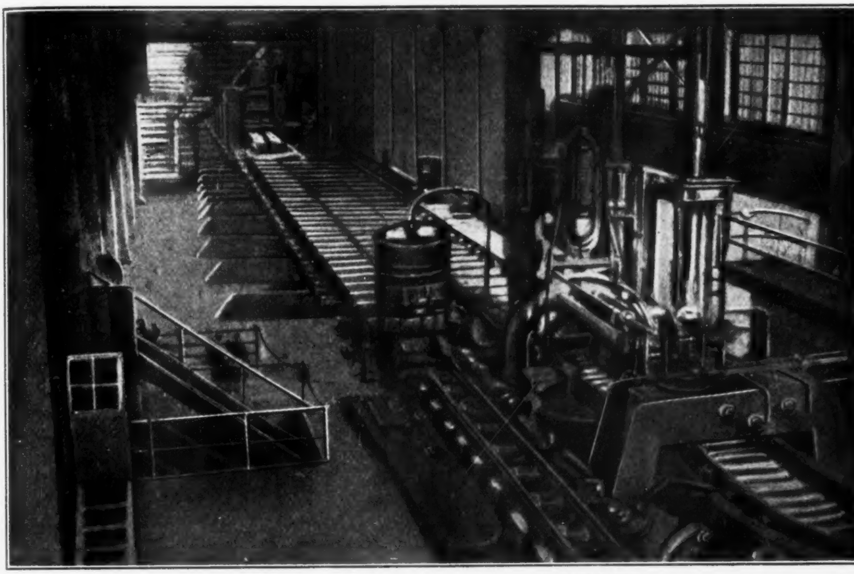

Figure 6—General Arrangement of Mill.

and light viscosity is used for general external lubrication. This is supplied by a gravity feed circulating system, the capacity of which has been increased by a number of changes to 3,000 gallons. The daily consumption of the cylinder and engine oil is as low as is compatible with the size and importance of the engine.

STRAIGHT MINERAL OIL VERSUS COMPOUNDED OIL FOR THE BEARINGS OF MARINE ENGINES NOT HAVING FORCED LUBRICATION*

By Lieutenant (J. G.) J. L. Kauffman, U. S. N. Member

THE purpose of this article is to compare the relative advantages and disadvantages of straight mineral oils with those of compounded oils when used to lubricate the bearings of marine reciprocating engines that *do not* have forced lubrication.

It is realized that a great deal of marine machinery is lubricated by forced-feed methods, but a study of the results of the tests given in this article may enable the operators of the older types of marine engines to materially reduce the cost of the oil used.

For a great many years after the steam engine came into use for marine propulsion, all the bearings were lubricated by fixed oils, that is, some form of animal or vegetable oils, such as lard, tallow, sperm or olive. These oils could be obtained very easily and cheaply at first,

* Reprinted by permission from the *Journal of the American Society of Naval Engineers*, Feb. 1917, p. 48.

and with the heavy, slow-moving machinery then used gave excellent results. As the number of engines increased and the amount of oil required became larger, the availability of the most favored of these, olive oil, decreased materially, thereby making the price excessive for the economical running of the machinery. At this time mineral lubricating oils were placed on the market. At first there was great opposition to these oils, but as the vegetable oils increased in price, tests were made which proved that a mixture of the fixed oils and mineral oils gave very good results. The percentage of mineral oil used in the mixture at the beginning was very small, but gradually increased until at the present time most compounded oils for marine-engine lubrication contain about 80 to 90 per cent. of straight mineral oil and from 10 to 20 per cent. of fixed oil.

As stated above, olive oil was the favorite and most largely used at first, but when compounding or blending with mineral oils began, various other fixed oils were used. The principal ones now used in compounding are rapeseed, cottonseed, tallow and lard oils. The first two are usually blown, that is, air is blown through them, to increase their viscosity. The first named, rapeseed oil or rapeoil (usual blown), is used almost entirely in the compounded oils furnished the Navy, while lard and tallow are used largely in the cheaper compounded oils. The former contains less free acid and will not oxidize or gum as readily as lard or tallow oils.

In the past, most authorities considered it absolutely necessary to have a compounded oil for marine reciprocating-engine lubrication, as water was used in addition to the oil for cooling the bearings. All fixed oils form a heavy, creamy emulsion when mixed with water, while most well refined mineral oils will not form an *intimate* emulsion and, therefore, it was thought, would be easily washed out of the bearing. In addition, the fact that all fixed oils decrease very little in viscosity with increase of temperature as compared with mineral oils, was used as an argument for compounded oils. Also it was considered impossible to produce straight mineral oils with sufficient viscosity to maintain the oil film under heavy loads.

As long as the price of compounded oils remained just slightly above the price of mineral oils there was little thought of substituting the latter for the former, but with an increase of about 50 per cent. in the price of desirable fixed oils, it was considered important to determine by actual tests if a straight mineral oil could be used instead of a compounded oil.

The Engineering Experiment Station at Annapolis, Md., recommended to the Navy Department that the tests be made, and the tests were authorized.

A straight mineral oil was sent to the Experiment Station, and, after making the usual chemical and physical tests, the oil was tried out on one of the older battleships having reciprocating engines *without* forced lubrication. The compounded oil was used on the starboard engine and the straight mineral oil on the port engine, the conditions of lubrication being the same on both. The test was made on two runs of 590 and 216 knots each, at a speed of about 14 knots. The following results of the test were reported.

(*a*) "There were no warm bearings for either engine during the period of the test.

(*b*) "The *straight mineral* oil does not readily emulsify with water, in fact, at no time did it form more than a 'skim milk' lather. This at first caused some nervousness among the oilers, but they soon realized that the bearings continued to run cool, and after a while were in favor of the new oil, as it makes a cleaner looking engine; wearing surfaces, such as crosshead guides, were always clear and bright; not covered with a thick, soapy lather.

(*c*) "The test oil, being lighter than the *compounded* oil, flowed more readily, and could be better and more economically applied at low speeds with few wicks.

(*d*) "The consumption of the two oils is about the same.

(*e*) "The present supply of *compounded* oil forms a very thick, creamy lather, which has to be washed out of crosshead guides and bearings very frequently. On the other hand, the *straight* mineral oil possesses practically no saponification quality, and at no time thickens or clogs up oil ways and bearing surfaces."

The following conclusions based on the above results were given by the Chief Engineer, Lieut. C. H. J. Keppler, U. S. Navy.

"As far as these limited tests of the new oil (straight mineral) are concerned it may be considered that:

(*a*) "The suitability of the *straight* mineral oil for service (naval) purposes on this type of engine is demonstrated.

(*b*) "The economy and efficiency as a lubricant of the two oils may be regarded as about equal. If any advantage, it is in favor of the *straight* mineral oil at moderate speeds.

(*c*) "While the *straight* mineral oil does not emulsify or form a thick lather, as long as a sufficient supply is maintained it serves as an efficient lubricant, and since it flows more readily the supply can be better regulated."

Although the above tests gave excellent results, it was thought necessary to make additional tests in order to study the action at higher speeds and under varying conditions. The Navy Department authorized tests on the U. S. Torpedo-boat *Bailey*, the test to be under the direction of the Engineering Experiment Station.

Two oils were selected for the test, one a *compounded* marine engine oil supplied to the Navy for the present contract year, the other a straight mineral oil which was found to form an emulsion when mixed with water. This latter oil was not specially refined for the purpose, and was taken to represent the cheaper grades of straight-run engine oils. . . .

An emulsion test was made on the two oils, using the Experiment Station's emulsion machine, and stirring at 1,500 r. p. m. for 5 minutes, 40 c.c. of oil and 40 c.c. of salt water. The straight mineral oil gave a "skim milk" emulsion which settled out into oil and water after standing for about 40 minutes. The compounded oil gave a thick creamy emulsion which failed to settle out.

The viscosity curves of the two oils show that although the difference in viscosity at engineroom temperature of 75 F. is over 400 seconds (Saybolt), the difference at bearing temperatures of 120 F. is only about 100 seconds. The above fact explains why the straight mineral oil flows more freely at all temperatures, and still is heavy enough to prevent its being squeezed out.

Before the practical test on board the *Bailey*, preliminary wick-feed tests were made using varying num-

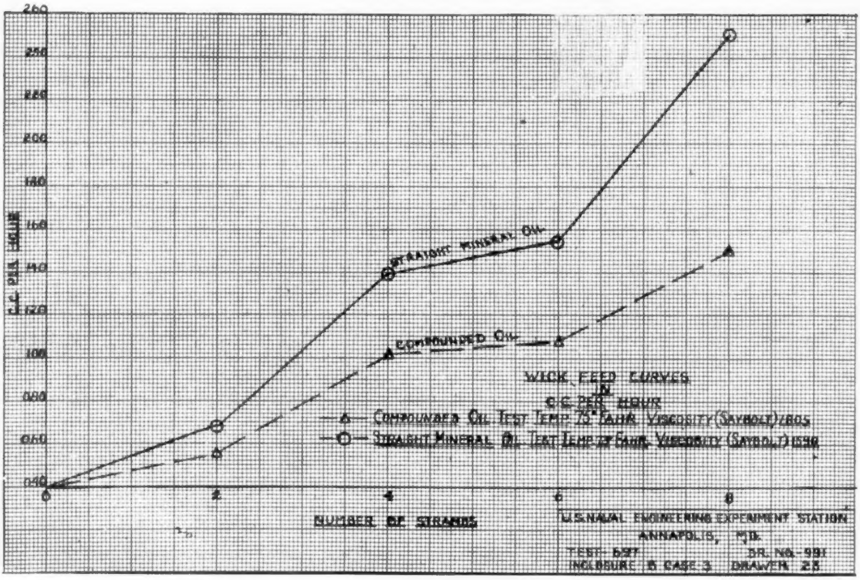

Figure 1

bers of strands and a one-half inch pipe. It was found that for this size oil pipe an increase in the number of strands up to *eight* gave increased flow of oil, but for ten strands and above the amount decreased. For this reason only eight strands were used on the tests on the *Bailey*.

Another preliminary test was made to show the relative rates of flow. The results of this test are shown graphically in figure 1. These curves show when using a half-inch pipe and eight strands, that the straight mineral oil flows about 60 per cent. faster than the compounded oil. . . .

The following general data are given in connection with the test:

1.	Number of engines	Two in same engine room, one starboard, one port
2.	Type of engine	Vertical, four cylinders, triple expansion
3.	Stroke	18 inches
4.	Diameter of cylinders, inches	20, 30½, 32, 32
5.	Diameter of crank, inches	7
6.	Type of lubrication	Wick feed
7.	Length of test, hours	3½
8.	R. P. M. (average both engines)	182
9.	Boiler pressure, pounds gage	220
10.	Vacuum, inches	23.5
11.	Engine-room temperature, deg. F	84
12.	Port crank bearing, drops of oil per minute	17.8
13.	Starboard crank bearing, drops of oil per minute	15.8

The oil reservoirs for the crank pins, wrist pins and crosshead guides are made fast to the engine cylinders. The oil reservoirs for the main bearings are directly on top of the bearings. The crank pins are lubricated through oil pipes running through the connecting rods. The water service as installed permanently is of the older type, running through the crank from one end of the engine, but

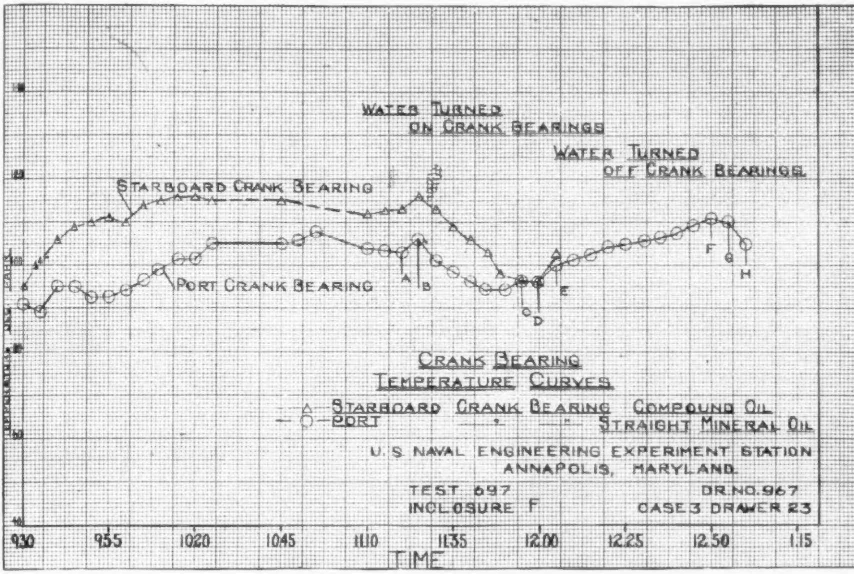

Figure 2

this was blanked off for the test, and a temporary pipe run with spray attachment, held in place above each crank pin. No water was used on the main bearings. . . .

Figure 2 shows the temperature curves of the crank bearings. These curves are considered the most important of those obtained, as they show the action of the oil under the varying conditions. *First*, it will be noted that the temperature of the port crank, using straight mineral oil, is lower than that of the starboard crank, using compounded oil, when oil alone was used. The only explanation offered is that the straight mineral oil flowed more freely, removing more heat per unit of time. *Second*, at A (figure 2), the temperature of both cranks having become practically constant, the water service *was turned* on each crank. This water service sprayed the water in the usual manner on one side of the crank bearings, opposite to the connection of the thermo-couple. From A to B the temperature rose in both cases about three degrees F., probably due to the water washing out the oil film at the start. But as soon as the mixture of oil and water formed the temperature decreased, until the point C was reached, where the temperature of both remained constant. At D the *water* was turned *off* both cranks. The temperature of both immediately went up. At this time the thermo-couple on the starboard engine, using compounded oil, broke, but as the action of the straight mineral oil was of primary importance, it was decided to continue the test without repairing the broken wires. From D to F the temperature of the port crank gradually increased, and from F to G remained constant, decreasing again to H. This indicated that the oil film had formed and was taking care of the heat generated.

A comparison of the crank bearing oil reservoir temperature curves with those of Figure 2 shows the existence of a peculiar condition;

namely, that the temperature of the oil in the crank reservoirs was *higher* than the temperature of the bearings at certain times. This condition is probably due to the cooling of the oil while passing through the oil pipes to the bearings. These pipes are cooler than the reservoirs on the cylinders, due to the circulation of air around the moving parts of the engines.

Before making these tests four points were decided upon on which it was desired to obtain information. These points will be taken up in order.

First: "Will straight mineral oil give as satisfactory lubrication as compounded oil when fed through wicks and when *no* water is used on the bearings?"

To obtain information on this first point, both engines were run under similar conditions using *wick* feed *only*. The curves on figure 2 from the beginning to point A show that the straight mineral oil lubricated more efficiently; that is, maintained lower temperatures than the compounded oil. The curves for the main bearings gave the opposite results, which are explained by the fact that the oil reservoirs were secured to the bearings; also both main-bearing temperatures remained constant after a short time. From the above it is considered reasonable to believe that the two oils have practically the same lubrication value; that is, will prevent seizing of the bearings, reduce the friction in direct proportion to their viscosity, and prevent rapid heating of the bearing above the melting point of the bearing metal.

Second: "Will straight mineral oil be washed out of the bearing *when the water is turned on*, thereby allowing the journal and brass to come in contact and wipe out the bearing metal?"

The section A to D of the curves on figure 2 proves conclusively that turning water on the bearing will not destroy the lubricating film, also that the bearing temperatures will be reduced. The curves from A to B on this figure indicate that at first the oil is washed out, but that the mixture of oil and water soon reduces the temperature.

Third: "Will straight mineral oil form a continuous oil film after the water is shut off?"

The section D to H of the curves on figure 2 shows that on turning *off* the water, the oil film will form very soon, and as soon as the normal bearing temperature has been reached the temperature will remain nearly constant.

From the results obtained on the tests enumerated above, the following conclusions were reached:

That at high speeds (180 r. p. m.) straight mineral oil will give as efficient lubrication as compounded oils.

That water running on the bearings will not break the oil film when straight mineral oil is used, and will cool the bearing, the mixture giving efficient lubrication.

That when the water is shut off the oil film will form, using either straight mineral oil or compounded oil.

That any straight mineral oil which will emulsify when mixed with salt water will give satisfactory results when used for the lubrication of marine reciprocating engines *not* having forced lubrication.

It is known, of course, that some merchant ships now use straight mineral oil and obtain satisfactory results, and it is thought that it will only be a question of time when all engines without forced lubrication will use it, having due regard for any peculiar or exceptional conditions, which may necessitate the use of compounded oils.